**The definition of variables for BEPS 4.0**

# The water and heat fluxes in the soil

## The data structure for soil

Table Properties belong to the whole soil profile

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| Flag | reserved |  |  |
| LAYERS | The number of layers |  | n\_layer |
| Zp | Depth of ponded water on the ground | m |  |
| Zsp | Depth of snow | m |  |
| r\_rain\_g | Rate of rainfall at ground | m/s |  |
| drainage\_class | The rate of drainage |  | r\_ drainage |
| Beta | Root decay rate |  | r\_root\_decay |
| psi\_min | The minimum psi for soil water stress | m |  |
| alpha | The power item in eq. 7 (Chen 2012, GBC) |  |  |
| fsoilw | Soil water stress |  | f\_soilwater |

Table Properties belong to the each soil horizon.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| ds[i] | Depth of a layer | m | d\_soil |
| R[i] | Fraction of root in a layer |  | f\_root |
| dt[i] | The weight calculated through fsoilw |  |  |
| thermal\_cond[i] | Thermal conductivity-dry | W m-1 K-1 |  |
| theta\_vfc[i] | Field capacity | M3 m-3 |  |
| theta\_vwp[i] | Permanent Wilting point | M3 m-3 |  |
| Fei[i] | Porosity | M3 m-3 |  |
| Ksat[i] | Saturated hydraulic conductivity | m s-1 |  |
| psi\_sat[i] | Water potential at saturation | m |  |
| b[i] | Cambell parameter b |  |  |
| rou\_s[i] | Soil bulk density | Kg m-3 | density\_soil |
| fraction\_OM[i] | Volume fraction of the organic matter | % | f\_org |
| ice\_ratio[i] | Fraction of ice in water |  |  |
| thetam[i] | Soil water content | M3 m-3 |  |
| Thetam\_prev[i] | Soil water content (last step) | M3 m-3 |  |
| Temp\_prev[i] | Soil temperature | K | temp\_soil\_p |
| Temp\_curr[i] | Soil temperature (last step) | K | temp\_soil\_c |
| f\_ice[i] | Ice ratio in the water |  | same as ice\_ratio? |
| psim[i] | Soil water potential | m |  |
| Fb[i] | Liquid water flow rate | m s-1 | r\_waterflow |
| Cs | Thermal conductivity ??? | W m-1 K-1 | c\_soil\_w |
| Ett | Et at each layer | Kg m-2 s-1 |  |
| G | Soil Heat flux | W m-2 | heatflux\_soil |

## Root profile

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| Beta | Extinction coefficient for a specific land cover | unitless | coef\_ex |
| LC | Land cover type | unitless |  |
| N | The number of layer | unitless | n\_layer |
| ds[i] | Depth of a layer | m | d\_soil |
| R[i] | Fraction of root in a layer | unitless | f\_root |

## Volumetric heat capacity for each layer (Cs, unit in J m-3 K-1)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| rou\_s[i] | Soil bulk density | Kg m-3 | density\_soil |
| Thetam[i] | Soil volumetric water content | fraction | thetam |
| ice\_ratio[i] | The ratio of ice in total soil water | fraction | same as ice\_ratio? |
| fraction\_OM[i] | Volume fraction of the organic matter | % | f\_org |
| XXXX | The numbers in eq are parameters |  |  |
| Cs[i] | Volumetric heat capacity | J m-3 K-1 | c\_soil\_j |

## the ratio of ice in the soil

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| Temp\_prev | Soil temp in last step | K | temp\_soil\_p |
| Temp\_curr | Soil temp. in curr step | K | temp\_soil\_c |
| Ice\_ratio | Ice ratio in last step | fraction |  |
| Cs[i] |  |  | which Cs? In W or J? |
|  |  |  |  |
| Lf0=3.34\*100000 | latent heat of fusion (liquid: solid) at 0 C | J kg-1 |  |
| Thetam\_prev |  | m3 m-3 | thetam\_p |
| Tehtam\_curr |  |  | thetam\_c |

## Soil thermal conductivity (lambda in the code)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| ki=2.1 | thermal conductivity of ice | W m-1 K-1 |  |
| kw=0.61 | thermal conductivity of water | W m-1 K-1 |  |
| Ks | Was from 4 parameters below | W m-1 K-1 |  |
| f\_sand |  |  |  |
| f\_silt |  |  |  |
| f\_clay |  |  |  |
| f\_org |  |  |  |
| k\_sat | Was from 7 parameters | W m-1 K-1 |  |
| P |  |  | what’s P? |
| f\_ice |  |  |  |
| theta\_m | Soil moisture |  | same as thetam? |
| k\_dry = 0.15 | Was from 3 parameters | W m-1 K-1 |  |

## Soil heat flux

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| G[i] | Soil heat flux | W m-2 | heatflux\_soil |
| LAYERS |  |  | n\_layer |
| Temp\_prev |  |  | temp\_soil\_p |
| Temp\_curr |  |  | temp\_soil\_c |
| Lambda | Thermal conducitivity |  |  |
| Cs | Vol heat capacity |  | c\_soil\_j |
| ds |  |  |  |
| Tair\_annual\_mean |  |  | temp\_air\_ann |
| DEPTH\_F | F ??? |  |  |

## Soil water balance

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| **Struct soil** |  |  | lack of list |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

## Soil water stress

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| **Struct Soil** | **Soil related parameter** |  | lack of list |
| **fw** | **Soil water stress** |  | lack of list |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

## Root water uptake

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| Rho\_w | Soil water density | Kg m-3 | density\_swater |
| Trans\_o | transpiration | Kg m-2 s-1 |  |
| Trans\_u | transpiration | Kg m-2 s-1 |  |
| Evap\_soil | Evap. of soil | Kg m-2 s-1 |  |
| Dt[i] | Weight of root & potential |  | same as dt? |
| Ett[i] |  | Kg m-2 s-1 |  |

# Leaf Temperature

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| Tair | Air temperature | Degree | temp\_air |
| Slope | the slope of the saturation vapor pressure-temperature curve |  |  |
| psychrometer | 0.066 | kPa K | psy\_air |
| VPD\_air | water pressure deficit | kpa |  |
| rho\_a | Air density | kg m-3 | density\_air0 |
| Cp\_ca | specific heat of moist air | kJ/kg/K | cp\_air |
| Gw\_o\_sunlit  Gw\_o\_shaded  Gw\_u\_sunlit  Gw\_u\_shaded | the total conductance for water from the intercellular space of the leaves to the reference height above the canopy | m s-1 |  |
| Gww\_o\_sunlit  Gww\_o\_shaded  Gww\_u\_sunlit  Gww\_u\_shaded | the total conductance for water from the surface of the leaves to the reference height above the canopy | m s-1 |  |
| Gh\_o\_sunlit  Gh\_o\_shaded  Gh\_u\_sunlit  Gh\_u\_shaded | total conductance for heat transfer from the leaf surface to the reference height above the canopy | m s-1 |  |
| Xcs\_o  Xcl\_o  Xcs\_u  Xcl\_u | the fraction of canopy covered by liquid water and snow, for overstory and understory |  |  |
| radiation\_o\_sun  radiation\_o\_shaded  radiation\_u\_sun  radiation\_u\_shaded | net radiation of leaves  ***angle?*** | w m-2 | netRadLeaf\_o\_sunlit  netRadLeaf\_o\_shaded  netRadLeaf\_u\_sunlit  netRadLeaf\_u\_shaded |
| Tc\_o\_sunlit  Tc\_o\_shaded  Tc\_u\_sunlit  Tc\_u\_shaded | the effective canopy temperature in K | K |  |

# Vcmax and Jmax (temperature function, nitrogen function, canopy-average sunlit and shaded)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| lai\_o | LAI for overstory | m2 m-2 |  |
| clumping | Clumping index |  |  |
| Vcmax0 | maximum photosynthetic carboxylation rate at 25 degree (leaf level) | µmol/m2/s |  |
| slope\_Vcmax\_N | slope of Vcmax-N curve |  |  |
| leaf\_N | leaf Nitrogen content mean value + 1 SD | g/m2 |  |
| CosZs | Cos(solar zenith angle) |  |  |
| Vcmax\_sunlit | Vcmax in canopy levle for sunlit leaf | µmol/m2/s |  |
| Vcmax\_shaded |  | µmol/m2/s |  |
| Jmax\_sunlit |  | µmol/m2/s |  |
| Jmax\_shaded |  | µmol/m2/s |  |

# Leaf area index (sunlit and shaded)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| stem\_o | overstory woody area |  |  |
| stem\_u | understory woody area |  |  |
| landcover | landcover type |  | LC |
| CosZs | cosine solar zenith angle |  |  |
| lai\_o | overstory LAI |  |  |
| clumping | clumping index |  |  |
| lai\_u | understory LAI |  |  |
| LAIo\_sunlit | overstory sunlit LAI |  | lai\_o\_sunlit |
| LAIo\_shaded | overstory shaded LAI |  | lai\_o\_shaded |
| LAIu\_sunlit | understory sunlit LAI |  | lai\_u\_sunlit |
| LAIu\_shaded | understory shaded LAI |  | lai\_u\_shaded |
| PAIo\_sunlit | overstory sunlit PAI |  | PAI\_o\_sunlit |
| PAIo\_shaded | overstory shaded PAI |  | PAI\_o\_shaded |
| PAIu\_sunlit | understory sunlit PAI |  | PAI\_u\_sunlit |
| PAIu\_shaded | understory shaded PAI |  | PAI\_u\_shaded |
|  |  |  |  |

# GPP and stomatal conductance

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| T\_leaf\_old | Leaf temperature of the last time step | K | temp\_leaf\_p |
| rad\_leaf | Leaf net shortwave radiation | W m-2 |  |
| air\_pres | Air pressure | Pa |  |
| ea | water vapour pressure above canopy | kPa | e\_actual |
| gbw | leaf laminar boundary layer conductance to H2O | m/s | g\_lb\_w |
| vcopt | the maximum carboxylation rate of Rubisco at 25 oC | µmol m-2 s-1 | vc\_opt |
| fw | an empirical scalar of soil water stress on stomatal conductance |  | f\_soilwater |
| b\_h2o | the intercept term in BWB model | mol m-2 s-1 |  |
| m\_h2o | the slope in BWB model |  |  |
| ca | atmospheric CO2 concentration | ppm |  |
| cii | initial intercellular CO2 concentration | ppm |  |
| T\_leaf\_c | leaf temperature | oC | temp\_leaf\_c |
| LE\_leaf | leaf latent heat flux | W m-2 | LH\_leaf |
| gsw | stomatal conductance to water vapour | m s-1 | Gs\_w |
| aphoto | net photosynthesis rate | µmol CO2 m-2 s-1 |  |
| ci | intercellular CO2 concentration | ppm |  |
| iphoton | incident photosynthetic photon flux density (PPFD) | µmol m-2 s-1 |  |
| wc | gross photosynthesis rate limited by Rubisco | µmol m-2 s-1 |  |
| wj | gross photosynthesis rate limited by light | µmol m-2 s-1 |  |
| j\_sucrose | net photosynthesis rate limited by sucrose synthesis | µmol m-2 s-1 |  |
| psguess | the guessed gross photosynthesis rate | µmol m-2 s-1 |  |
| gbc | leaf laminar boundary layer conductance to CO2 | mol m-2 s-1 | g\_lb\_c |
| rh\_leaf | relative humidity at leaf surface. (0-1) |  |  |
| T\_leaf\_k | leaf temperature | K | temp\_leaf\_K |
| gs\_co2\_mole | stomatal conductance to CO2 | mol m-2 s-1 |  |
| gs\_h2o\_mole | stomatal conductance to H2O | mol m-2 s-1 |  |
| cs | CO2 concentration at leaf surface | ppm |  |
| b\_co2 | the intercept term in BWB model: b\_h2o/1.6 | mol m-2 s-1 |  |
| m\_co2 | the slope in BWB model: m\_h2o/1.6 |  |  |
| gammac | CO2 compensation point | ppm |  |
| jmopt | the maximum potential electron transport rate at 25 deg C | µmol m-2 s-1 |  |
| jmax | the maximum potential electron transport rate | µmol m-2 s-1 |  |
| vcmax | the maximum velocities of carboxylation of Rubisco | µmol m-2 s-1 |  |
| kct | Michaelis-Menten constant for CO2 | ppm | km\_co2 |
| ko | Michaelis-Menten constant for O2 | mmol mol-1 | km\_o2 |
| tau | the specificity of Rubisco for CO2 compared with O2 |  |  |
| rd | leaf dark respiration | µmol m-2 s-1 | resp\_ld |
| rdz | leaf dark respiration at 25 oC | µmol m-2 s-1 | resp\_ld25 |
| j\_photon | the flux of electrons through the thylakoid membrane | µmol m-2 s-1 |  |
| bc | a function of enzyme kinetics | ppm |  |
| b\_ps | coefficients in Farquhar’s model |  |  |
| a\_ps | coefficients in Farquhar’s model |  |  |
| e\_ps | coefficients in Farquhar’s model |  |  |
| d\_ps | coefficients in Farquhar’s model |  |  |
| alpha\_ps | coefficient in the cubic equation of the coupled leaf photosynthesis and stomatal conductance models |  |  |
| beta\_ps | coefficient in the cubic equation of the coupled leaf photosynthesis and stomatal conductance models |  |  |
| gamma\_ps | coefficient in the cubic equation of the coupled leaf photosynthesis and stomatal conductance models |  |  |
| theta\_ps | coefficient in the cubic equation of the coupled leaf photosynthesis and stomatal conductance models |  |  |
| denom | denominator of the coefficients in the cubic equation of the coupled leaf photosynthesis and stomatal conductance models |  |  |
| p\_cubic | the coefficient in the cubic equation |  |  |
| q\_cubic | the coefficient in the cubic equation |  |  |
| r\_cubic | the coefficient in the cubic equation |  |  |
| Qroot | the term to derive the roots of the cubic equation |  |  |
| Rroot | the term to derive the roots of the cubic equation |  |  |
| ang\_L | the term to derive the roots of the cubic equation |  |  |
| root1 | a root of the cubic equation |  |  |
| root2 | a root of the cubic equation |  |  |
| root3 | a root of the cubic equation |  |  |
| minroot | the minimum root of the cubic equation |  |  |
| midroot | the middle root of the cubic equation |  |  |
| maxroot | the maximum root of the cubic equation |  |  |
| Aquad | the coefficient in the quadratic equation |  |  |
| Bquad | the coefficient in the quadratic equation |  |  |
| Cquad | the coefficient in the quadratic equation |  |  |
| ps\_1 | temporary variable for the quadratic equation |  |  |
| delta\_1 | temporary variable for the quadratic equation |  |  |
| product | temporary variable for the quadratic equation |  |  |

# Snow pack

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| depth\_snow\_last  depth\_water\_last | Depth of snow and water from last step | m | depth\_snow\_p  depth\_water\_p |
| depth\_snow  depth\_water | Depth of snow and water in this step | m |  |
| evapo\_snow\_g | Sublimation of snow from ground in this step | mm/s |  |
| percent\_snow\_o  percent\_snow\_u  percent\_snow\_g | Percentage of snow cover on overstorey, understorey, ground (calculated by mass) | 0-1 |  |
| area\_snow\_o  area\_snow\_u | Area of snow at overstorey and understorey | m2/m2 |  |
| areaMax\_snow\_o  areaMax\_snow\_u | Maximum area of snow at overstorey and understorey | m2/m2 |  |
| percentArea\_snow\_o  percentArea\_snow\_u | Percentage of snow cover on overstorey, understorey, ground **(calculated by area)** | 0-1 |  |
| snowrate\_o  snowrate\_u  snowrate\_g | Falling rate of snow on overstorey, understorey and ground | m/s |  |
| density\_water | Density of water | kg/m3 |  |
| precipitation | Precipitation rate over the canopy | m/s |  |
| density\_new\_snow | Density of newly fallen snow (function of air temperature) | kg/m3 |  |
| density\_snow | Density of snow before stage 1 | kg/m3 |  |
| density\_snow\_output | Density of snow after stage 2 | kg/m3 |  |
| temp\_air | Air temperature |  |  |
| mass\_snow\_o  mass\_snow\_u  mass\_snow\_g | Mass of snow per area **stays** on canopy, overstorey and understorey, ground | kg/m2 |  |
| massMax\_snow\_o  massMax\_snow\_u | Maximum amount of snow intercepted | kg/m2 |  |
| massStep\_snow\_o  massStep\_snow\_u | Mass of snow being intercepted **in this step** per area | kg/m2 |  |
| change\_depth\_snow | Change of snow depth caused by snow fall on the ground | m |  |
| length\_step | Length of calculation steps in BEPS, set as 5 minutes, that is 300 seconds | s |  |
| mass\_snow\_melted  mass\_snow\_frozen | Newly melted or frozen snow in this step | kg/m2 |  |
| temp\_g  temp\_last\_g | Ground temperature from this step and last step |  | temp\_g\_p |
| cp\_ice | Specific heat of ice | J/kg/ |  |
| latent\_fusion | Latent heat for fusion | J/kg |  |
| melt\_depth\_snow, frozen\_depth\_snow | Melting or frozen of snow in depth | m |  |
| Melt\_dpeth\_water  frozen\_depth\_water | Melting or Freezing of water in depth | m |  |
| albedo\_v\_snow  albedo\_n\_snow | Albedo of snow in visible and near infrared band in this step | 0-1 |  |
| albedo\_v\_Newsnow  albedo\_n\_Newsnow | Albedo of **new snow** in visible and near infrared band in this step | 0-1 |  |
| albedoLast\_v\_snow  albedoLast\_n\_snow | Albedo of snow in visible and near infrared band **from last step** | 0-1 | albedo\_v\_snow\_p  albedo\_n\_snow\_p |

# Sensible heat

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Unit** | **Suggested Var. name** |
| Qhc\_o | Sensible heat from canopy, overstorey | W/m2 | SH\_o |
| Qhc\_u | Sensible heat from canopy, understory | W/m2 | SH\_u |
| Qhg | Sensible heat from ground | W/m2 | SH\_g |
| H\_o\_sunlit  H\_o\_shaded  H\_u\_sunlit  H\_u\_shaded | Sensible heat from leaves, overstorey and understorey, sunlit and shaded | W/m2 | SH\_o\_sunlit  SH\_o\_shaded  SH\_u\_sunlit  SH\_u\_shaded |
| tempL\_o\_sunlit  tempL\_o\_shaded  tempL\_u\_sunlit  tempL\_u\_shaded | Temperature of leaves, overstorey and understorey, sunlit and shaded |  |  |
| temp\_air | Air temperature |  |  |
| rh\_air | Relative humidity of air | 0-100 |  |
| density\_air | Air density at 0 | kg/m3 | density\_air0 |
| cp\_ air | Specific heat of moist air above canopy | J/kg/ |  |
| vpd\_air | Water vapor pressure deficit at reference height | kPa |  |
| Gheat\_o\_sunlit  Gheat\_o\_shaded  Gheat\_u\_sunlit  Gheat\_u\_shaded | Aerodynamic heat conductance of leaves, overstorey and understory, sunlit and shaded | m/s |  |
| Gheat\_g | Aerodynamic conductance on ground surface | m/s |  |
| lai\_o\_sunlit  lai\_o\_shaded  lai\_u\_sunlit  lai\_u\_shaded | Leaf area index, overstorey and understorey, sunlit and shaded (including stem) | m2/m2 |  |
| temp\_g | Ground surface temperature |  |  |

# Net Radiation-canopy (direct, diffuse, reflected, longwave)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| netRad\_o | Net radiation for canopy, overstorey | W/m2 |  |
| netRad\_u | Net radiation for canopy, understorey | W/m2 |  |
| netRad\_g | Net radiation for ground | W/m2 |  |
| netShortRad\_o  netShortRad\_u  netShortRad\_g  netLongRad\_o  netLongRad\_u  netLongRad\_g | Net shortwave radiation and long wave radiation on canopy, overstorey and understorey and ground | W/m2 |  |
| shortRad\_global | Global incoming solar radiation | W/m2 |  |
| cosZs | Cosine value of solar zenith angle | 0-1 | CosZs |
| ratio\_cloud | A simple value to assess intensity of cloud, to facilitate impartation of direct and diffuse shortwave radiation | 0-1 |  |
| shortRad\_dir  shortRad\_df | Direct and diffuse solar radiation on top of the canopy | W/m2 |  |
| netShortRad\_o\_dir  netShortRad\_o\_df  netShortRad\_u\_dir  netShortRad\_u\_df  netShortRad\_g\_dir  netShortRad\_g\_df | Net shortwave direct and diffuse radiation, overstorey and understorey and ground | W/m2 |  |
| albedo\_o  albedo\_u  albedo\_g | Albedo of canopy: overstorey, understorey and ground. (considering snow) | 0-1 |  |
| albedo\_v\_os  albedo\_n\_os  albedo\_v\_us  albedo\_n\_us  albedo\_v\_gs  albedo\_n\_gs | Albedo of canopy, overstorey and understorey and ground, in visible and near infrared band, considering snow on canopy and ground surface | 0-1 |  |
| albedo\_v\_o  albedo\_n\_o  albedo\_v\_u  albedo\_n\_u  albedo\_v\_g  albedo\_n\_g | Albedo of canopy, overstorey and understorey, in visible and near infrared band, without considering snow on canopy and ground surface | 0-1 |  |
| percentArea\_snow\_o  percentArea\_ snow\_u  percent\_ snow\_g | Percentage of area covered by snow on overstorey, understorey and ground | 0-1 |  |
| albedo\_snow\_v  albedo\_snow\_n | Albedo of snow in visible and near infrared band | 0-1 |  |
| lai\_o  lai\_u | Leaf area index, overstorey and understorey (exclude stem) | m2/m2 |  |
| e\_saturate | Saturated water vapor potential at this temperature | kPa |  |
| e\_actual | Actual water vapor potential | kPa |  |
| temp\_air  temp\_o  temp\_u  temp\_g | Air temperature  temperature of overstorey  temperature of understorey  temperature of ground |  |  |
| emissivity\_air | emissivity of air | 0-1 |  |
| emissivity\_o  emissivity\_u  emissivity\_g | emissivity of overstorey, understorey and ground | 0-1 |  |
| sb\_constant | Stephen Boltzman constant | 5.670373×10−8 W m−2 K−4 |  |
| cosQ\_o  cosQ\_u | An indicator to decribe distribution angles of canopy, slightly related with LAI | 0-1 |  |
| longRad\_air  longRad \_o  longRad\_u  longRad\_g\_ | Long wave radiation emitted by air, overstorey, understorey and ground | W/m2 |  |
| gap\_o\_df  gap\_u\_df | Gap fraction of diffuse radiation and long wave radiation for overstorey and understorey | 0-1 |  |
| netRadLeaf\_o\_sun  netRadLeaf\_o\_shaded | net radiation on sunlit and shaded leaves of overstorey | W/m2 | better to use sunlit |
| netRadLeaf\_u\_sun  netRadLeaf\_u\_shaded | net radiation on sunlit and shaded leaves of understorey | W/m2 | better to use sunlit |
| netShortRad\_o\_dir  netShortRad\_o\_df  netShortRad\_u\_dir  netShortRad\_u\_df | Net shortwave direct and diffuse radiation, overstorey and understorey | W/m2 |  |
| netLongRad\_o  netLongRad\_u | Net long wave radiation on canopy, overstorey and understorey | W/m2 |  |
| lai\_os  lai\_us | LAI for overstorey and understorey, including leave area and stem area |  |  |
| lai\_o\_sunlit  lai\_o\_shaded  lai\_u\_sunlit  lai\_u\_shaded | LAI for overstorey and understorey, sunlit and shaded leaves |  |  |
| gap\_o\_dir  gap\_u\_dir | Gap fraction of **direct shortwave** radiation for overstorey and understorey | 0-1 |  |

# Evaporation - soil surface

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| evapo\_soil | Evaporation from soil surface | mm/s (10-3kg/m2/s) |  |
| evapo\_water\_g  evapo\_snow\_g | Evaporation from water surface and snow surface on ground | mm/s  (10-3kg/m2/s) |  |
| netRad\_g | Net radiation on ground | W/m2 |  |
| temp\_g | Ground surface temperature |  |  |
| rh\_g | Relative humidity at ground (set it as the same value as air humidity above canopy) | 0-100 |  |
| density\_air\_g | Air density near ground | kg/m3 |  |
| cp\_air\_g | Specific heat of air near ground | J/kg/ |  |
| vpd\_g | Water vapor pressure deficit near ground | kPa |  |
| slope\_vapor\_g | Slope of saturated vapor potential to temperature at ground |  |  |
| psy\_g | Psycrometer constant on ground |  |  |
| Gheat\_g | Aerodynamic conductance on soil surface | m/s |  |
| Gwater\_g | Conductance of water at soil surface (program use resistance) | m/s |  |
| latent\_water | Latent heat to vaporize water | J/kg | LH\_water |
| latent\_snow | Latent heat to vaporize snow | J/kg | LH\_snow |
| temp\_air | air temperature |  |  |
| percent\_snow\_g | Percentage of snow cover on ground | 0-1 |  |
| depth\_water  depth\_snow | Depth of water and snow on ground | m |  |
| density\_water | Density of water | g/m3 |  |
| density\_snow | Density of snow | g/m3 |  |
| swc\_g | Soil water content on the first layer of soil | m3/m3 |  |
| porosity\_g | Soil porosity on the first layer of soil |  |  |

# Evaporation-canopy

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| evapo\_water\_o  evapo\_water\_u | Evaporation of intercepted rain from overstorey and understorey | mm/s |  |
| evapo\_snow\_o  evapo\_snow\_u | Evaporation of intercepted snow from overstorey and understorey | mm/s |  |
| latentLw\_o\_sunlit  latentLw\_o\_shaded  latentLw\_u\_sunlit  latentLw\_u\_shaded | Latent heat caused by the evaporation of intercepted **rain** at sunlit and shaded leaves on overstorey and understorey, leaf level | J/m2/s | LHw\_o\_sunlit  LHw\_o\_shaded  LHw\_u\_sunlit  LHw\_u\_shaded |
| latentLs\_o\_sunlit  latentLs\_o\_shaded  latentLs\_u\_sunlit  latentLs\_u\_shaded | Latent heat caused by the evaporation of intercepted **snow** at sunlit and shaded leaves on overstorey and understorey, leaf level | J/m2/s | LHs\_o\_sunlit  LHs\_o\_shaded  LHs\_u\_sunlit  LHs\_u\_shaded |
| Gwater\_o\_sunlit  Gwater\_o\_shaded  Gwater\_u\_sunlit  Gwater\_u\_shaded | Aerodynamic conductance for both **water and snow**, overstorey and understorey | m/s |  |
| vpd\_air | Water vapor pressure deficit in atmosphere | kPa |  |
| density\_air | Air density at 0 | kg/m3 |  |
| cp\_ air | Specific heat of moist air above canopy | J/kg/ |  |
| slope\_vapor\_air | Slope of saturated vapor potential to temperature |  |  |
| tempL\_o\_sunlit  tempL\_o\_shaded  tempL\_u\_sunlit  tempL\_u\_shaded | Temperature of leaves, overstorey and understorey, sunlit and shaded |  |  |
| psy\_air | Psychometer constant |  |  |
| lai\_o\_sunlit  lai\_o\_shaded  lai\_u\_sunlit  lai\_u\_shaded | Leaf area index, overstorey and understorey, sunlit and shaded (including stem) | m2/m2 |  |
| percent\_water\_o  percent\_water\_u | Percentage of rain water covers on overstorey and understorey | 0-1 |  |
| percent\_snow\_o  percent\_snow\_u | Percentage of snow covers on overstorey and understorey | 0-1 |  |
| latent\_water | Latent heat to vaporize water, change with air temperature | J/kg | LH\_water |
| latent\_snow | Latent heat to vaporize snow | J/kg | LH\_snow |

# Transpiration (sunlit, shaded, overstorey)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| trans\_o  trans\_u | Transpiration from overstorey and understorey | mm/s |  |
| latentLt\_o\_sunlit  latentLt\_o\_shaded  latentLt\_u\_sunlit  latentLt\_u\_shaded | Latent heat at **leaf level** caused by transpiration at sunlit and shaded leaves on overstorey and understorey, leaf level | J/m2/s | LHt\_o\_sunlit  LHt\_o\_shaded  LHt\_u\_sunlit  LHt\_u\_shaded |
| lai\_o\_sunlit  lai\_o\_shaded  lai\_u\_sunlit  lai\_u\_shaded | Leaf area index, overstorey and understorey, sunlit and shaded (including stem) | m2/m2 |  |
| latent\_water | Latent heat to vaporize water, change with air temperature | J/kg | LH\_water |
| vpd\_air | Water vapor pressure deficit in atmosphere | kPa |  |
| density\_air | Air density at 0 | kg/m3 |  |
| cp\_ air | Specific heat of moist air above canopy | J/kg/ |  |
| slope\_vapor\_air | Slope of saturated vapor potential to temperature |  |  |
| tempL\_o\_sunlit  tempL\_o\_shaded  tempL\_u\_sunlit  tempL\_u\_shaded | Temperature of leaves, overstorey and understorey, sunlit and shaded |  |  |
| psy\_air | Psychometer constant |  |  |
| lai\_o\_sunlit  lai\_o\_shaded  lai\_u\_sunlit  lai\_u\_shaded | Leaf area index, overstorey and understorey, sunlit and shaded (including stem) | m2/m2 |  |
| Gtrans\_o\_sunlit  Gtrans\_o\_shaded  Gtrans\_u\_sunlit  Gtrans\_u\_shaded | Total conductance for transpiration. (tandem of stomatal conductance and aerodynamic conductance) | m/s |  |

# Rainfall stage 1,2

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| percent\_water\_o  percent\_water\_u | Percentage of rain water covers on overstorey and understorey | 0-1 |  |
| lai\_o  lai\_u | Leaf area index, overstorey and understorey (**not including stem**) | m2/m2 |  |
| clumping | Clumping index | 0-1 |  |
| mass\_water\_o  mass\_water\_u | Mass of water per area remains on canopy, overstorey and understorey | kg/m2 |  |
| massMax\_water\_o  massMax\_water\_u | Maximum amount of water intercepted | kg/m2 |  |
| massStep\_water\_o  massStep\_water\_u | Mass of water being intercepted **in this step** per area | kg/m2 |  |
| precipitation | The rate of precipitation , **overstorey** | m/s |  |
| Precipitation\_o  precipitation\_u  precipitation\_g | The rate of precipitation onoverstorey, understorey and ground | m/s |  |
| density\_water | Density of water | kg/m3 |  |
| length\_step | Length of calculation steps in BEPS, set as 5 minutes, that is 300 seconds | s |  |

# Surface temperature

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| temp\_air  rh | Air temperature and relative humidity | 0-100 | rh\_air |
| depth\_snow  depth\_water | Depth of snow and water on ground in this step | m |  |
| capacity\_heat\_soil1 | Heat capacity of layer 1 soil | J/m2/K |  |
| capacity\_heat\_soil0 | Heat capacity of layer 0 soil. (it is a virtual soil layer) | J/m2/K |  |
| Gheat\_g | Aerodynamic conductance of heat on ground | m/s |  |
| depth\_soil1 | Depth of soil in layer 1 | m |  |
| density\_snow | Density of snow in this step | kg/m3 |  |
| tempL\_u | Leaf temperature of understorey |  |  |
| netRad\_g | Net radiation on ground | W/m2 |  |
| evapo\_soil  evapo\_water\_g  evapo\_snow\_g | Evaporation from soil surface, pond water on ground and snow pack on ground | mm/s |  |
| lambda\_soil1 | Thermal conductivity of first layer soil | W/m/K |  |
| percent\_snow\_g | Percentage of snow coverage on ground | 0-1 |  |
| heat\_flux\_soil1 | The heat flux from 1st layer soil to the next soil layer | W/m2 |  |
| temp\_ground  temp\_any0  temp\_snow  temp\_soil0  temp\_snow1  temp\_snow2 | Temperature of ground, temperature of the virtual layer (Tm[0] in original codes), temperature of snow, temperature of soil pack layer 1 and layer 2 |  |  |
| temp\_ground\_last  temp\_any0\_last  temp\_snow\_last  temp\_soil0\_last  temp\_snow1\_last  temp\_snow2\_last | The temperature information from last step |  |  |
| heat\_flux | The amount of heat flux from ground to soil | W/m2 |  |

# Conductance package

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| GstomatalW\_o\_sunlit  GstomatalW\_o\_shaded  GstomatalW\_u\_sunlit  GstomatalW\_u\_shaded | Stomatal conductance for water, overstorey and understorey | m/s | Gs\_w\_o\_sunlit  Gs\_w\_o\_shaded  Gs\_w\_u\_sunlit  Gs\_w\_u\_shaded |
| G\_o\_a  G\_o\_b  G\_u\_a  G\_u\_b | Aerodynamic and boundary layer conductance for leaves at overstorey and understorey, | m/s |  |
| Gheat\_o\_sunlit  Gheat\_o\_shaded  Gheat\_u\_sunlit  Gheat\_u\_shaded | Aerodynamic heat conductance of leaves, overstorey and understory, sunlit and shaded | m/s |  |
| Gwater\_o\_sunlit  Gwater\_o\_shaded  Gwater\_u\_sunlit  Gwater\_u\_shaded | Aerodynamic conductance for both **water and snow**, overstorey and understorey | m/s |  |
| Gtrans\_o\_sunlit  Gtrans\_o\_shaded  Gtrans\_u\_sunlit  Gtrans\_u\_shaded | Total conductance for transpiration. (tandem of stomatal conductance and aerodynamic conductance) | m/s |  |
| Gcarbon\_o\_sunlit  Gcarbon\_o\_shaded  Gcarbon\_u\_sunlit  Gcarbon\_u\_shaded | Total conductance for carbon uptake (tandem of stomatal conductance and aerodynamic conductance | m/s |  |

# Meteorology package

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| temp | Temperature of all kind |  | temp\_air |
| rh | Relative humidity of all kind | 0-100 | rh\_air |
| density\_air | Air density near ground | kg/m3 |  |
| cp\_air | Specific heat of air | J/kg/ |  |
| vpd | Water vapor pressure near ground | kPa |  |
| slope\_vapor | Slope of saturated water vapor potential to temperature at ground |  |  |
| psy | Psycrometer constant on ground |  | psy\_air |
| e\_saturate | Saturated water vapor potential at this temperature | kPa |  |
| e\_actual | Actual water vapor potential | kPa |  |
| sp\_humidity | Specific humidity | g/g | sphd\_air |

# Aerodynamic conductance

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| canopy\_height\_o | Canopy height | m |  |
| canopy\_height\_u | height of understory | m |  |
| zz | the\_heigt\_to\_measure\_wind\_speeld | m/s |  |
| omega | clumping\_index |  | clumping |
| temp\_air | air temperature | °C |  |
| U | wind speed | m/s | wind\_sp |
| QH | sensible heat flux from overstorey | W/m2 | SH\_o\_p |
| lai\_o, lai\_u |  |  |  |
| ra\_o | air resistance for overstory | s/m |  |
| ra\_u | air resistance for understory | s/m |  |
| ra\_g | air resistance for ground | s/m |  |
| G\_o\_a | air conductance for overstory | m/s |  |
| G\_o\_b | leaf boundary for overstory | m/s |  |
| G\_u\_a | air conductance for understory | m/s |  |
| G\_u\_b | leaf boundary for understory | m/s |  |
| kh\_o  kh\_u |  |  |  |
| lw=0.3 | leaf charcteristic width =0.3 for BS |  |  |
| sigma=5 | shelter factor =5 for BS |  |  |
| rb\_o,  rb\_u | leaf boundary layer resistance for overstory and understory |  |  |
| k=0.4 | von Karman's constant |  |  |
| beta=0.5 | Bowen's ratio |  |  |
| cp=1010 | specific heat of air | J/kg/K |  |
| rho=1.225 | density of air at 15 C | kg/m3 | density\_air |
| gg=9.8 | gravitational acceleration | m/s2 |  |
| n=5.0 |  |  |  |
| nu\_lower | viscosity |  |  |
| uf |  |  |  |
| psi |  |  |  |
| d | displacement height | m |  |
| z0 | roughness length | m |  |
| ustar | friction velocity | m/s |  |
| L |  |  |  |
| Le |  |  |  |
| uh | wind speed at height h |  |  |
| ud | wind speed at height d |  |  |
| gamma |  |  |  |
| Re | Reynold's number |  |  |
| Nu | Nusselt number |  |  |
| alfac | a for carbon |  |  |
| alfaw | a for water |  |  |
| ram |  |  |  |
| un\_d,  un\_t, |  |  |  |

# Autotrophic respiration and NPP

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| lc | land cover |  | LC |
| gpp\_o, gpp\_u | GPP for overstory and understory | gC m-2 |  |
| lai\_yr | annual average LAI |  |  |
| lai | LAI |  |  |
| temp\_air | air temperature | °C |  |
| temp\_soil | soil temperature | °C |  |
| COSTheta | solar zenith angle |  | CosZs |
| npp\_o, npp\_u | NPP for overstory and understory | gC m-2 |  |
| biomass |  |  |  |
| biomass\_leaf\_o  biomass\_stem\_o  biomass\_root\_o  biomass\_leaf\_u  biomass\_stem\_u  biomass\_root\_u | biomass of leaf, stem and  root for overstory and understory |  |  |
| respir\_croot\_o  respir\_root\_o  respir\_stem\_o  respir\_leaf\_o  respir\_croot\_u  respir\_root\_u  respir\_stem\_u  respir\_leaf\_u | maintenance respiration of leaf, stem coarse root and root for overstory and understory |  |  |
| lai\_u  lai\_max\_o  lai\_max\_u | lai for understory  max. lai for overstory and understory |  |  |
| coef\_leaf\_respir  coef\_stem\_respir  coef\_root\_respir  coef\_fineroot\_respir | respiration coefficients of leaf, stem root and fine root |  |  |
| ra |  |  |  |
| q10 | Q10 |  |  |
| op\_t=25.0; |  |  | temp\_opt25 |

# Heterotrophic respiration and NEP

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Meaning** | **Units** | **Suggested Var. name** |
| Ccd, Cssd, Csmd, Cfsd, Cfmd, Csm, Cm, Cs, Cp | carbon pools | kgC m-2 |  |
| Coef[30]  fw,fcr,fl,ffr,kw\_cd,kcr\_cd,kl\_sl, kfr\_fl,km\_p,ks\_p,kssd\_a,kssd\_sm, kssd\_s, ksmd\_a, ksmd\_sm,kfsd\_a, kfsd\_m, kfsd\_s, kfmd\_a, kfmd\_m,  kcd\_a,cd\_m,kcd\_s,ksm\_a,ksm\_s, km\_a,km\_s,ks\_a,ks\_m,kp\_a,kp\_m | C transfer coefficient from pool x to y | kgC m-2hr-1 |  |
| Cw, Ccr,Cl, Cfr | carbon of stem,coarse root,leaf and fine root | gCm-2 |  |
| dCw,dCcr,dCl,dCfr,dCcd,dCssd,dCsmd,dCfsd,dCfmd,dCsm,dCm,dCs,dCp | carbon changes of each pool | gCm-2 |  |
| lambda  lambda\_t  lambda\_w | carbon conductivity  t: temperature effect  w: water effect |  |  |
| Stxt | soil texture ID |  | soiltype |
| tsoil | soil temperature |  | temp\_soil |
| theta | soil water content |  |  |
| fei | soil porosity |  |  |
| npp\_yr | a fraction of NPP transferred to biomass C pools | gCm-2 |  |
| npp | total NPP | gCm-2 |  |
| NEP | NEP | gCm-2 |  |